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The Importance of Groundwater to Fish Habitat: Base Flow Characteristics for Three Gulf Region Rivers

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ABSTRACT

Caissie, D. 1991. The Importance of Groundwater to Fish Habitat: Base Flow Characteristics for Three Gulf Region Rivers. Can. Data Rep. Fish. Aquat. Sci. 814: 25p.

The importance of groundwater to fish habitat and productive capacity of streams is discussed in this report through a presentation of groundwater related data for three Gulf Region rivers. Groundwater flow data were calculated for the Wilmot River in Prince Edward Island, the Kouchibouguac River in New Brunswick, and the Ste. Genevieve River in Newfoundland using the daily discharge hydrographs. The base flow recession constant, which is an indication of groundwater discharge during periods of no precipitation, was calculated for selected recession periods. An estimate of groundwater discharge (base flow) was also calculated using a graphical hydrograph separation technique. From the graphical hydrograph separation technique, monthly base flow and the ratio of base flow to total flow were calculated.

RÉSUMÉ

Caissie, D. 1991. The Importance of Groundwater to Fish Habitat: Base Flow Characteristics for Three Gulf Region Rivers. Can. Data Rep. Fish. Aquat. Sci. 814: 25p.

L'importance des eaux souterraines pour l'habitat du poisson et la capacité productive du cours d'eau est discutée dans ce rapport par une présentation de données reliés aux eaux souterraines de trois rivières de la région du golfe. Les données des eaux souterraines ont été calculées à l'aide des hydrogrammes des débits journaliers pour la rivière Wilmot à l'Ile-du-Prince-Edouard, la rivière Kouchibouguac au Nouveau-Brunswick et la rivière Ste. Genevieve à Terre-Neuve. Les constantes de récession de l'écoulement de base, indiquant le débit des eaux souterraines pour de périodes sans précipitation, ont été calculées pour des périodes de récession choisies. Une estimation du débit des eaux souterraines (écoulement de base) a également été calculée en utilisant une méthode graphique de séparation des hydrogrammes. A l'aide de la méthode graphique de séparation des hydrogrammes, les débits de base mensuels et le rapport du débit de base sur le débit total ont été calculés.

INTRODUCTION

Fish habitat and the productive capacity of streams is influenced by many hydrological phenomena such as floods, droughts, baseflow, and streamflow variations. For example, Frenette et al. (1984) showed the importance of discharge to young Atlantic salmon (*Salmo salar*) by correlating the number of fish to different flows. The importance of the basin's hydrology to the stream's productivity was also reflected in another of Frenette's studies, in which he discussed the effects of floods and droughts on a population of Atlantic salmon (Frenette 1987). Streamflow or river discharge is one component of the hydrologic cycle which strongly influences the fisheries resource. Streamflow can be further subdivided into the following components: surface runoff, interflow, channel precipitation, and groundwater flow. The groundwater flow (or base flow) has proven to be very important for fish and their habitats (Benson 1953). Groundwater flow tends to stabilize stream discharge and also reduces extreme water temperatures by providing a warmer temperature regime during winter and cooler temperatures during summer. Warmer stream temperatures during winter are especially favourable for overwintering fish (Cunjak and Power 1986) and eggs (Cunjak et al. 1986). In summer, stream temperature tends to be cooler because of groundwater influx to the channel. The cooler stream temperature has a better capacity for dissolved oxygen, and maintains suitable habitat conditions, even during periods of extremely high air temperature. Therefore, a groundwater-fed stream is more stable, less flashy, and more productive (Bovee 1982; Edwards et al. 1979).

To understand the effects of groundwater flow on fish habitat, one has to be able to quantify this flow from the streamflow components. This can be accomplished through studies involving different streamflow processes. One such study is the groundwater-surface water interaction study in which the two streamflow components are separated graphically (MacLennan and Bray 1989). Other methods of estimating groundwater discharge involve the use of seepage meters as shown by Lee (1977) and by Lee and Cherry (1978). Difficulties are sometimes encountered when using seepage meters to estimate the groundwater contribution, because certain reaches of the stream are groundwater discharge zones while others are groundwater recharge zones. Zones of groundwater recharge are identified where the water is entering the stream's bed whereas zones of groundwater discharge are identified where the groundwater is exiting the stream's bed (Freeze and Cherry 1979). Groundwater discharge can also be studied using a series of groundwater observation wells. The observation wells are used to develop rating curves relating the levels within the wells to the groundwater discharge during the recession (Rasmussen and Andreasen 1959). The stream is in recession when groundwater discharge is the only streamflow component present. Groundwater discharge is then estimated throughout the year using the rating curve. Another approach for groundwater analysis is the study of the streamflow hydrograph at a gauged station (Linsley et al. 1949). The streamflow hydrograph, which is the sum of all streamflow components, is separated into different components and groundwater (or base flow) is identified.

In this study, a streamflow hydrograph analysis was carried out to differentiate base flow from the total streamflow. The term "base flow" was used in this study rather than "groundwater flow" because base flow includes not only the groundwater discharge but also the water that comes from other storage such as lakes, swamps, and the channel itself.

The objective of the present study is a first step at better understanding the hydrology of the Gulf Region as it pertains to base flow and its potential impact on fisheries resources. To realize this objective, base flow characteristics were estimated for three rivers in the region. These characteristics are: 1) base flow recession parameters, 2) monthly base flow, and 3) ratio of monthly base flow to total flow.

STUDY AREA

The three study rivers are located in the Gulf Region (Figure 1). They are: the Kouchibouguac River in New Brunswick; the Wilmot River in Prince Edward Island; and the Ste. Genevieve River in Newfoundland. These three river systems are part of different geological and hydrological regions. Both the Kouchibougac and Wilmot River are in the Carboniferous-Permian bedrock formation (Macpherson, 1972). This bedrock formation is characterized by sandstone, shale and some coal. The Ste. Genevieve River is situated in the Cambrian-Ordovician-Silurian bedrock formation (Macpherson, 1972) which is characterized by undeformed sediments.

Two of the three study rivers (Kouchibouguac and Ste. Genevieve Rivers) are in close proximity to "index" rivers, selected by the Department of Fisheries and Oceans (DFO), for which fish movement and densities are monitored. This may permit a comparison of the hydrologic characteristics detailed in this report.

The Wilmot River has a drainage area of 45.4 km^2 while the Kouchibouguac River drains 177 km^2. The Ste. Genevieve River, which is the largest, has a drainage area of 306 km^2. The Wilmot and Kouchibouguac Rivers have similar geomorphologic characteristics (Figures 2, 3; Table 1). A significant portion of the Ste. Genevieve River basin comprises of lakes, unlike the other two basins (Figure 4). Other geomorphologic characteristics of the three studied rivers are presented in Table 1.

GROUNDWATER ANALYSIS

Streamflow components

To study the groundwater flow or base flow using the discharge hydrograph, it is important to understand its different streamflow components. As shown in Figure 5, these components are: a) surface runoff or direct runoff, b) channel precipitation, c) interflow, and d) groundwater flow or base flow (Viessman et al. 1977). Surface runoff refers to the flow of water over the land's surface, which occurs during and immediately after rainfall. The rate of surface runoff depends on the surface-type with different surfaces being characterized by different surface runoff coefficients. Channel precipitation is defined as the amount of precipitation that falls directly into the stream; which is concurrent with the precipitation. Interflow is water that infiltrates the ground but does not reach the groundwater table; it occurs during part of the surface runoff period and generally continues to the end of the surface runoff. Interflow, being within the upper layer of soil, travels faster than the deeper types of groundwater. The last component of the discharge hydrograph is the groundwater flow or base flow. Base flow is the water that keeps the river flowing following the end of the surface runoff. Part of the base flow is water that has reached the water table and is reentering the stream through groundwater discharge zones. A portion of the base flow can also originate from basin storage (e.g. lakes and swamps). Because of the absence of the other components, the base flow recession period is often used for groundwater discharge analysis.

Base flow recession analysis

The base flow recession analysis method used in this study consists of studying characteristics of the streamflow hydrographs for different base flows during recession. The hydrograph is in a state of base flow recession immediately following the end of the surface runoff period. At this point the precipitation has also ceased for a period of time (Figure 5). This portion of the hydrograph (base flow recession) has the particular characteristic of following an exponentially decreasing curve. The base flow recession period of the hydrograph as shown by Barnes (1939) and by Hall (1968) follows one of the following exponential equations:

$$[1] \qquad Q_t = Q_0 K_r^t \quad \text{or} \quad Q_t = Q_0 e^{-a_1 t} \qquad \text{with } e^{-a_1} = K_r$$

$$[2] \qquad Q_t = Q_0 \exp(-a_2 t^n)$$

where Q_t is the discharge at time t and Q_0 is the discharge at time zero (or initial discharge). K_r (the recession constant), a_1, a_2, and n are base flow recession parameters. In [1] and [2] e and exp represent the natural logarithm.

Equation [1] yields a straight line when the logarithm of discharge is plotted against time. To obtain a straight line with equation [2], the logarithmic transformation is applied twice on discharge and once on time. These transformed variables can be studied graphically to identify recession periods. Once a series of recession periods are identified, the equation parameters can be estimated and compared for different flows or different river systems. The geometric mean, another calculated parameter, reflects the magnitude of streamflow during the recession. It is preferred over the arithmetic mean when dealing with exponentials. The geometric mean is obtained by the following equation:

$$[3] \qquad X_g = \exp\left(\sum_{i=1}^{N} (\ln Q_i) \right)$$

with N representing the duration of the base flow recession period in days, Q_i the discharge of the i-th day, and ln the natural logarithm.

From a fisheries perspective, it is important to understand the base flow recession curve characteristics for at least two reasons: a) they give an indication of the rate of depletion of storage (or groundwater) for the basin, and b) they provide a forecasting tool for drought and low flow analyses. In anticipation of a drought, the base flow recession curve can be used to estimate the degree of low flow. Mitigative measures can be implemented to protect fishes and their habitats in multi abstraction watercourses.

Hydrograph separation techniques

It is important to estimate the base flow throughout the year. This estimate permits a comparison of groundwater contributions from one year to the next or between drainage basins. The base flow hydrograph can be obtained through a separation of the streamflow components. Several techniques have been proposed (Linsley et al. 1949) and many of them are described in Cormier (1986). Some of these techniques can be analyzed analytically but most of them are graphical. It is not the purpose of this report to present all of the possible methods but rather, to appreciate the differences in the outcome of such methods; a few of them are discussed below.

In the application of any hydrograph separation technique, one must first look at the hydrograph and identify the beginning and the end of surface runoff. These two points are identified by A and C (or C') on Figure 6. The beginning of surface runoff is easier to establish than the end because it is often associated with a distinct rise in discharge. One method of identifying the end of surface runoff is to apply the following rule of thumb (Linsley et al. 1958):

$$[4] \qquad N = A^{0.2}$$

where, N = duration of runoff in days, and A = drainage area in square miles

Another method of identifying the end of surface runoff is to plot the logarithm of discharge versus time. If the base flow recession curve follows an exponential curve, as described in the previous section, then the transformed hydrographs

should yield a straight line following the end of runoff.

Assuming that the beginning and the end of surface runoff can be estimated, the hydrograph separation technique consists of drawing a straight line between the two points (i.e. between points A and C, Figure 6). A second method consists of continuing the base flow of the previous recession until the hydrograph reaches its peak. This is shown as point B (Figure 6). A straight line is then drawn from point B to point C. The third method is the straight, horizontal line separation. This method consists of drawing a straight horizontal line from the beginning of the surface runoff to the intersection on the discharge hydrograph (point C' on Figure 6).

These methods are fairly simple to apply provided that the hydrograph is well defined by a single storm event. Hydrographs resulting from more than one storm or from a combination of snow melt and precipitation are often complex and the separation more difficult. Such complex hydrographs are often observed in northern countries like Canada. Meyboom (1961) and Chernaya (1969) described a method of separation which can be utilized in these situations. This technique consists of studying the hydrograph for a longer period (e.g. annual) rather than on a storm event basis (Meyboom 1961). If the logarithm of discharge is plotted against time, low flows often result in a straight line. This method, also known as the Envelope Method, consists of joining the low flows by straight lines on a log-transformed graph.

RESULTS

Base flow recession curve characteristics

The data used in this study were daily mean river discharges (Environment Canada, Inland Waters Directorate, 1970..1988) and daily precipitation (Environment Canada, Atmospheric and Environment Service, 1970..1988). Base flow recession periods were identified using streamflow hydrographs and precipitation records. However, precipitation records did not always help identify the base flow recession period because precipitation did not necessarily produce an increase in discharge. This was observed during winter when precipitation is often in the form of snow and also during the summer when infiltration, transpiration and evaporation are high. Base flow recession periods identified for the Ste. Genevieve River in 1978 are shown in Figure 7. Once the recession periods were identified, a log plot of discharge vs time (equation [1]) and a log log plot of discharge vs log of time (equation [2]) of each recession period were studied graphically. The selected base flow recession periods were then fitted to equation [1] and [2] by regression analysis. The results of this analysis are presented for Wilmot River (Table 2), for Kouchibouguac River (Table 3) and for Ste. Genevieve River (Table 4).

Each table contains information on the start, the end and the duration of the base flow recession period. The end of the recession period was identified by an increase in discharge as shown in Figure 7. K_r was calculated using the relation in equation [1], while X_0 was calculated using equation [3] The coefficients a_1, a_2, and n, of [1] and [2], are the parameters of the recession equations and Q_0 the initial discharge. The last two columns of these tables were part of the regression analysis with r_1^2 representing the explained variance (or fit) of equation [1] and r_2^2 representing the explained variance of equation [2]. These last two variables give an indication of which equation best represents the base flow recession characteristics. The results of the explained variance for equation [1] (r_1^2) and for equation [2] (r_2^2) shows no evidence that one equation is better than the other. It was also noted from these tables that Ste. Genevieve River had more identifiable base flow recession periods than the other two rivers.

Monthly and annual base flow characteristics

The identification of the end of surface runoff using the log transformed plot was very difficult to apply because the transition was often gradual. In addition, even when the base flow recession curve fitted the exponential curve well, a straight line was not always evident. Snowmelt and precipitation were also factors contributing to the complexity of some hydrographs, which made it very difficult to identify the end of surface runoff. In view of this, the Envelope hydrograph separation technique was chosen. Straight lines were then drawn joining low flows of the log transformed graph (Figure 8a). This process was carried out systematically each year, for every river system. Once the separation was completed, the equation of each exponential line was determined by identifying the end points. Knowing the parameter of each line, the base flow hydrograph was reconstructed (the hatched area of Figure 8b). Then, using the base flow hydrographs, the monthly base flows were calculated (Tables, 5-7). These tables show that the months with the highest base flow contribution are April-May for Wilmot and Kouchibouguac River, and May-June for Ste. Genevieve River. The variation in annual mean base flow is consistent between drainage basins, with coefficients of variation ranging from 20.9% to 24.2% (Tables, 5-7).

In base flow studies, the ratio of base flow to total flow is used as a variable to show when the groundwater or base flow contribution is the most significant (MacLennan and Bray 1989). This ratio is also used as an index to compare different basins in a studied region. Tables 8-10 present the results of the ratio of base flow to total flow for the three studied rivers. These tables show the importance of base flow during the summer period with ratios in the 0.80 to 0.90 range with relatively low coefficients of variation for Wilmot and Ste. Genevieve Rivers. Kouchibouguac River shows lower ratios of base flow to total flow for these months and values ranging from 0.47 to 0.62 throughout the year (Table 9).

Discussion

This report presents groundwater related data for three Gulf Region rivers obtained by calculating base flow characteristics. These characteristics include base flow recession parameters, monthly base flow, and monthly ratio of base flow to total flow. Further development of the present study could include a study of the base flow recession constant K_r as a function of average discharge (X_q) and comparing the results for different river systems. Streamflow characteristics, such as those used by Frenette et al. (1984), could be studied using not only total flows (Frenette et al. 1984) but also base flows in the analysis. This could help to identify which streamflow component best explains size or density of fish populations.

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Table 1. Drainage basin characteristics

River System	Wilmot R.	Kouchbouguac R.	Ste. Genevieve R.
Station Number	01CB004	01BR001	02YA001
Latitude	46° 23' 35" N	46° 44' 36" N	51° 08' 18" N
Longitude	63° 39' 35" W	65° 12' 17" W	56° 47' 32" W
Drainage Area (km^2)	45.4	177	306
Swamp Area (km^2)	0.0	16.5	41.3
Total Length of Stream (km)	49.6	114	118
Stream Order	3	4	N/A
Basin Perimeter (km)	28.6	59.0	88.0

Table 2. Wilmot River recession curve characteristics

Year	Start	End	Days	Kr	Xg	a_1	a_2	n	Qo	r_1^2	r_2^2
1972	27	42	16	0.916	0.246	0.0873	0.1396	0.905	0.572	0.946	0.963
1972	145	160	16	0.966	0.08	0.0346	0.0966	0.679	1.34	0.975	0.994
1972	257	274	18	0.995	0.363	0.0052	0.0365	0.476	0.388	0.790	0.930
1972	348	356	9	0.978	0.769	0.0224	0.0160	1.187	0.847	0.992	0.976
1973	5	18	14	0.968	0.937	0.0328	0.1337	0.569	1.23	0.960	0.995
1973	44	63	20	0.971	0.574	0.0293	0.0376	0.940	0.776	0.987	0.995
1974	13	21	9	0.965	0.395	0.0359	0.0545	0.811	0.453	0.998	0.990
1974	40	50	11	0.981	0.339	0.0193	0.0419	0.757	0.382	0.969	0.979
1974	276	283	10	0.990	0.282	0.0100	0.0253	0.623	0.292	0.999	0.990
1974	353	365	13	0.978	0.826	0.0224	0.1390	0.425	0.974	0.976	0.987
1975	126	136	9	0.940	2.75	0.0620	0.2344	0.514	3.65	0.991	0.991
1976	323	331	9	0.978	1.011	0.0224	0.0240	1.052	1.13	0.964	0.947
1976	346	355	10	0.972	0.925	0.0284	0.0509	0.819	1.08	0.966	0.986
1977	15	25	11	0.978	0.593	0.0223	0.1132	0.457	0.671	0.976	0.984
1977	175	185	11	0.988	0.821	0.0125	0.0198	0.831	0.875	0.972	0.972
1977	306	316	11	0.980	1.06	0.0202	0.0243	0.890	1.16	0.971	0.910
1978	17	25	9	0.951	1.48	0.0498	0.5755	0.234	1.18	0.998	0.958
1978	60	73	14	0.990	0.689	0.0100	0.0317	0.609	0.739	0.994	0.990
1979	45	55	11	0.964	0.385	0.0371	0.0238	1.199	0.465	0.999	0.994
1979	331	339	9	0.968	1.16	0.0322	0.0266	1.122	1.34	0.988	0.982
1980	27	42	16	0.978	0.718	0.0222	0.0457	0.768	0.86	0.986	0.996
1980	352	360	9	0.965	0.924	0.0356	0.0346	1.039	1.08	0.974	0.964
1981	17	30	14	0.984	0.659	0.0161	0.0256	0.832	0.734	0.990	0.989
1981	62	73	12	0.982	0.918	0.0187	0.0568	0.640	1.04	0.955	0.993
1981	179	194	16	0.982	0.987	0.0185	0.0589	0.616	1.14	0.990	0.982
1981	240	262	23	0.995	0.491	0.0047	0.0253	0.529	0.525	0.919	0.948
1982	41	50	10	0.969	0.935	0.0320	0.0275	1.131	1.11	0.974	0.930
1982	124	133	10	0.949	2.37	0.0525	0.1626	0.594	3.08	0.990	0.997
1982	182	200	19	0.983	0.625	0.0171	0.4239	0.207	0.808	0.904	0.980
1983	43	60	18	0.987	0.45	0.0129	0.0651	0.496	0.504	0.984	0.962
1983	166	176	11	0.971	0.872	0.0291	0.0249	1.088	1.02	0.993	0.975
1984	63	74	12	0.965	1.1	0.0361	0.2006	0.442	1.39	0.982	0.984
1984	200	220	21	0.985	0.723	0.0147	0.0290	0.785	0.634	0.967	0.902
1985	108	123	16	0.970	0.905	0.0305	0.2615	0.362	1.15	0.988	0.960
1986	132	144	12	0.987	0.557	0.0130	0.0421	0.601	0.602	0.961	0.968
1986	120	130	11	0.960	0.772	0.0406	0.0454	0.958	0.949	0.992	0.995
1987	137	147	11	0.974	0.654	0.0265	0.0532	0.744	0.752	0.987	0.992
1987	354	362	9	0.983	0.712	0.0176	0.0248	0.865	0.766	0.955	0.979
1988	72	83	12	0.977	0.808	0.0228	0.0553	0.686	0.932	0.955	0.967
1988	127	137	11	0.965	1.93	0.0358	0.0670	0.774	2.34	0.988	0.994
1988	336	350	15	0.975	0.731	0.0251	0.0694	0.649	0.869	0.985	0.964

Table 3. Kouchibouguac River recession curve characteristics

Year	Start	End	Days	Kr	Xg	a_1	a_2	n	Qo	r_1^2	r_2^2
1970	14	31	18	0.949	0.919	0.0519	0.1024	0.828	1.6	0.958	0.983
1970	38	51	14	0.901	1.89	0.1040	0.6257	0.446	4.25	0.975	0.996
1970	352	365	14	0.982	1.53	0.0183	0.0175	1.072	1.76	0.985	0.957
1971	57	74	18	0.973	2.17	0.0273	0.0573	0.814	2.92	0.960	0.979
1971	127	143	17	0.908	8.39	0.0962	0.2167	0.740	19.6	0.992	0.997
1972	31	44	14	0.967	0.55	0.0328	0.0803	0.719	0.708	0.979	0.995
1972	60	73	14	0.983	0.64	0.0170	0.0229	0.936	0.728	0.977	0.986
1972	350	366	17	0.955	2.33	0.0451	0.0708	0.888	3.57	0.988	0.992
1973	7	19	13	0.957	2.19	0.0437	0.0549	0.919	2.86	0.999	0.999
1973	52	62	11	0.970	1.38	0.0305	0.0409	0.907	1.63	0.984	0.992
1973	200	213	14	0.956	0.985	0.0451	0.1326	0.664	1.42	0.975	0.990
1974	38	49	12	0.988	0.753	0.0123	0.0168	0.930	0.816	0.982	0.977
1974	175	181	7	0.916	1.43	0.0677	0.1271	0.817	1.85	0.995	0.992
1975	2	10	9	0.977	1.17	0.0235	0.0475	0.748	1.3	0.978	0.995
1975	40	54	15	0.973	0.57	0.0271	0.0367	0.901	0.694	0.995	0.995
1975	66	77	12	0.977	0.861	0.0236	0.0552	0.702	0.991	0.992	0.997
1975	167	174	8	0.903	3.02	0.1025	0.1130	0.987	4.47	0.986	0.991
1975	216	223	8	0.925	0.803	0.0784	0.0321	1.438	1.05	0.997	0.991
1976	16	25	10	0.975	1.56	0.0257	0.0417	0.818	1.76	0.988	0.983
1976	69	78	10	0.952	1.76	0.0497	0.0954	0.773	2.27	0.986	0.997
1976	313	323	11	0.907	3.46	0.0978	0.2296	0.728	6.31	0.947	0.988
1976	346	358	13	0.946	1.19	0.0552	0.0816	0.872	1.7	0.994	0.998
1977	15	28	14	0.970	1.11	0.0309	0.0584	0.802	1.39	0.980	0.996
1977	45	56	12	0.979	0.731	0.0212	0.0311	0.853	0.821	0.997	0.991
1977	177	186	10	0.894	3.22	0.1125	0.0608	1.275	5.32	0.997	0.993
1977	338	347	10	0.944	1.65	0.0579	0.1145	0.772	2.24	0.977	0.992
1978	14	25	12	0.915	2.6	0.0889	0.1398	0.896	4.81	0.951	0.971
1978	55	69	15	0.971	1.11	0.0298	0.0416	0.934	1.42	0.967	0.983
1978	223	238	16	0.978	0.294	0.0221	0.1783	0.368	0.354	0.912	0.896
1978	336	350	15	0.976	0.513	0.0247	0.0403	0.870	0.637	0.978	0.991
1979	10	25	16	0.934	3.33	0.0680	0.1462	0.784	6.23	0.969	0.989
1979	43	56	14	0.933	1.98	0.0694	0.0961	0.924	3.34	0.981	0.986
1979	124	133	10	0.873	7.52	0.1362	0.3575	0.670	15.7	0.989	0.994
1979	240	249	10	0.966	0.778	0.0346	0.0384	0.998	0.931	0.940	0.955

Table 3. Kouchibouguac River recession curve characteristics (con't)

Year	Start	End	Days	Kr	Xg	a_1	a_2	n	Qo	r_1^2	r_2^2
1980	2	11	10	0.926	1.87	0.0768	0.0839	0.967	2.66	0.999	0.999
1980	37	49	13	0.962	0.776	0.0392	0.0634	0.862	1.22	0.973	0.991
1980	143	160	18	0.944	2.24	0.0576	0.0832	0.902	3.85	0.986	0.992
1980	353	364	12	0.919	1.71	0.0840	0.0503	1.246	2.8	0.997	0.972
1981	20	32	13	0.967	0.801	0.0335	0.0365	0.997	1.0	0.996	0.987
1981	139	150	12	0.931	4.25	0.0714	0.4350	0.456	7.59	0.888	0.976
1981	235	245	11	0.941	1.14	0.0608	0.1408	0.696	1.57	0.992	0.992
1981	356	365	10	0.931	3.17	0.0717	0.2129	0.626	4.7	0.978	0.996
1982	19	31	13	0.968	1.15	0.0327	0.0519	0.859	1.44	0.989	0.995
1982	50	64	15	0.966	1.16	0.0348	0.0556	0.849	1.5	0.992	0.997
1982	122	131	10	0.902	8.24	0.1031	0.0564	1.278	13.2	0.997	0.980
1982	185	198	14	0.933	1.91	0.0694	0.0632	1.160	1.90	0.937	0.865
1982	341	350	10	0.927	1.91	0.0753	0.1923	0.694	2.95	0.956	0.984
1983	46	60	15	0.977	1.03	0.0229	0.0320	0.942	1.25	0.961	0.971
1983	159	167	9	0.912	2.95	0.0919	0.0980	1.044	4.6	0.965	0.965
1983	267	277	10	0.899	0.528	0.1068	0.2174	0.802	1.08	0.939	0.956
1984	10	25	16	0.966	0.991	0.0341	0.0332	1.007	1.28	0.998	0.995
1984	138	150	13	0.907	6.49	0.0971	0.2414	0.703	12.9	0.985	0.997
1984	247	255	9	0.880	1.16	0.1275	0.1173	1.087	2.06	0.980	0.976
1985	109	123	15	0.947	3.51	0.0550	0.2440	0.545	5.76	0.968	0.992
1985	345	359	15	0.976	0.409	0.0240	0.0778	0.634	0.5	0.978	0.998
1985	199	210	12	0.935	1.02	0.0673	0.1196	0.838	1.61	0.963	0.980
1986	5	19	15	0.981	0.486	0.0190	0.0708	0.964	0.555	0.999	0.999
1986	60	76	16	0.985	0.461	0.0149	0.0356	0.747	0.53	0.942	0.987
1986	127	140	14	0.936	3.21	0.0663	0.0596	1.067	5.09	0.995	0.991
1986	346	359	14	0.954	1.34	0.0468	0.0339	1.147	1.85	0.996	0.987
1987	41	55	15	0.991	0.703	0.0089	0.0104	0.969	0.75	0.974	0.960
1987	64	81	17	0.991	0.573	0.0088	0.0083	1.042	0.62	0.982	0.991
1987	110	118	9	0.838	10.9	0.1769	0.1432	1.106	22.6	0.996	0.994
1987	351	365	15	0.974	1.54	0.0263	0.0294	0.951	1.84	0.988	0.997
1988	5	18	14	0.977	1.000	0.0234	0.0293	0.9110	1.16	0.997	0.991
1988	60	76	17	0.955	1.95	0.0458	0.0447	1.012	2.82	0.998	0.999
1988	355	366	12	0.971	1.19	0.0299	0.0351	0.985	1.44	0.987	0.977

Table 4. Ste. Genevieve River recession curve characteristics

Year	Start	End	Days	Kr	Xg	a_1	a_2	n	Qo	r_1^2	r_2^2
1970	19	33	15	0.987	6.07	0.0129	0.0140	0.995	6.68	0.991	0.995
1970	51	60	10	0.984	5.37	0.0156	0.0153	1.024	5.78	0.998	0.994
1970	218	235	18	0.971	7.62	0.0290	0.0461	0.842	9.74	0.995	0.990
1970	299	309	11	0.969	7.57	0.0308	0.0368	1.015	9.23	0.960	0.937
1970	351	365	15	0.987	8.9	0.0129	0.0145	0.982	9.3	0.989	0.992
1971	20	40	21	0.989	5.69	0.0108	0.0220	0.808	6.48	0.983	0.991
1971	55	70	16	0.986	4.56	0.0139	0.0200	0.896	5.1	0.983	0.991
1971	155	170	16	0.962	22.4	0.0391	0.0294	1.095	29.7	0.995	0.998
1971	192	212	21	0.964	10	0.0370	0.0809	0.803	16.2	0.972	0.965
1971	340	355	16	0.987	5.31	0.0134	0.0240	0.828	5.95	0.983	0.992
1972	7	18	12	0.993	4.12	0.0072	0.0127	0.752	4.33	0.997	0.514
1972	49	63	15	0.986	1.30	0.0137	0.0363	0.682	1.44	0.994	0.990
1972	182	196	15	0.962	20.7	0.0390	0.0966	0.689	27.7	0.991	0.986
1972	205	217	13	0.963	13.4	0.0377	0.0340	1.076	17	0.992	0.952
1972	353	366	14	0.975	5.76	0.0258	0.0285	0.989	6.91	0.995	0.993
1973	2	20	19	0.983	4.03	0.0173	0.0208	0.932	4.7	0.999	0.997
1973	51	65	15	0.979	4.85	0.0215	0.0175	1.090	5.66	0.995	0.994
1973	75	90	16	0.983	3.98	0.0171	0.0216	0.914	4.42	0.997	0.994
1973	228	245	18	0.977	7.24	0.0231	0.0571	0.720	9.06	0.984	0.992
1974	60	80	21	0.991	2.19	0.0092	0.0118	0.921	2.41	0.998	0.998
1974	213	227	15	0.972	9.17	0.0285	0.0234	1.108	11.4	0.987	0.978
1974	350	365	18	0.973	7.48	0.0270	0.0552	0.775	9.34	0.986	0.995
1975	60	80	21	0.992	2.7	0.0083	0.0098	0.954	2.94	0.997	0.997
1975	181	196	16	0.968	10.66	0.0324	0.0215	1.181	13.8	0.989	0.971
1975	214	223	10	0.953	5.57	0.0482	0.0257	1.251	6.82	0.993	0.998
1975	346	356	11	0.950	9.11	0.0510	0.0526	1.000	11.9	0.993	0.997
1976	13	27	15	0.982	5.66	0.0179	0.0219	0.926	6.65	0.999	0.999
1976	69	80	12	0.992	4.27	0.0091	0.0130	0.815	4.47	0.997	0.994
1976	170	191	22	0.971	9.03	0.0294	0.0670	0.746	12.6	0.989	0.992
1976	329	341	13	0.969	10	0.0315	0.0284	1.096	12.4	0.989	0.905
1977	40	74	35	0.984	4.83	0.0165	0.0211	0.936	6.46	0.999	0.999
1977	94	111	18	0.957	12.7	0.0436	0.0588	0.938	19.5	0.984	0.984
1977	163	177	15	0.956	28.8	0.0447	0.0248	1.215	38.8	0.997	0.991

Table 4. Ste. Genevieve River recession curve characteristics (con't)

Year	Start	End	Days	Kr	Xg	a_1	a_2	n	Qo	r_1^2	r_2^2
1977	335	350	16	0.978	5.06	0.0222	0.0379	0.858	6.17	0.978	0.988
1978	70	110	41	0.997	3.44	0.0029	0.0058	0.808	3.65	0.995	0.983
1978	166	178	13	0.964	18	0.0363	0.0460	0.985	23.7	0.969	0.940
1978	182	198	17	0.969	12	0.0311	0.0832	0.705	16	0.969	0.988
1978	218	235	18	0.978	7.62	0.0227	0.0600	0.719	9.68	0.963	0.982
1978	337	350	14	0.970	4.98	0.0300	0.0359	0.961	6.17	0.993	0.994
1979	14	24	11	0.953	7.92	0.0488	0.0561	0.956	10.2	0.994	0.997
1979	39	65	27	0.976	7.37	0.0248	0.0403	0.879	10.6	0.992	0.996
1979	145	156	12	0.968	15.7	0.0330	0.0045	1.769	18.1	0.981	0.989
1979	343	352	10	0.970	7.82	0.0304	0.0525	0.783	9	0.998	0.995
1980	2	11	10	0.978	7.49	0.0227	0.0281	0.930	8.35	0.996	0.998
1980	50	79	30	0.986	4.29	0.0142	0.0190	0.928	5.35	0.998	0.998
1980	88	102	15	0.984	3.41	0.0162	0.0206	0.915	3.82	0.993	0.994
1980	345	366	22	0.968	8.9	0.0327	0.0433	0.926	12.9	0.997	0.998
1981	2	18	17	0.974	4.86	0.0263	0.0322	0.940	6.05	0.997	0.998
1981	20	33	14	0.980	4.16	0.0207	0.0218	0.770	3.87	0.986	0.997
1981	75	89	15	0.976	5.68	0.0241	0.0278	0.993	6.9	0.983	0.982
1981	135	151	17	0.972	15.7	0.0284	0.0130	1.290	19.6	0.996	0.990
1981	154	164	11	0.983	11.6	0.0173	0.0335	0.728	12.6	0.989	0.971
1981	241	255	15	0.974	4.61	0.0262	0.0476	0.761	5.47	0.987	0.971
1981	356	364	9	0.961	8.65	0.0400	0.0829	0.725	10.3	0.994	0.999
1982	50	71	22	0.987	3.54	0.0132	0.0132	1.022	4.1	0.994	0.996
1982	75	85	11	0.977	4.23	0.2290	0.0241	1.013	4.8	0.993	0.990
1982	100	112	13	0.965	7.91	0.0354	0.0232	1.177	9.8	0.999	0.993
1982	158	173	16	0.975	22.3	0.0252	0.0212	1.106	27.6	0.984	0.971
1982	208	221	14	0.968	7.3	0.0324	0.0475	0.845	8.94	0.996	0.987
1982	277	288	12	0.973	4.36	0.0278	0.0190	1.255	5.29	0.964	0.902
1982	328	337	10	0.961	8.16	0.0397	0.0210	1.395	10.2	0.973	0.871
1982	341	349	9	0.965	7.17	0.0352	0.0464	0.896	8.3	0.996	0.999
1982	352	365	14	0.965	6.29	0.0355	0.0358	0.994	7.9	0.999	0.999
1983	14	34	21	0.977	4.12	0.0232	0.0287	0.939	5.25	0.998	0.999
1983	40	61	22	0.978	3.18	0.0204	0.0200	1.036	4.02	0.992	0.969

Table 4. Ste. Genevieve River recession curve characteristics (con't)

Year	Start	End	Days	Kr	Xg	a_1	a_2	n	Qo	r_1^2	r_2^2
1983	62	70	9	0.988	2.47	0.0122	0.0105	1.132	2.67	0.982	0.954
1983	83	98	16	0.978	3.97	0.0227	0.0365	0.829	4.7	0.999	0.994
1983	160	170	11	0.972	12.3	0.0287	0.0537	0.752	14.1	0.996	0.984
1983	228	237	10	0.984	8.37	0.0160	0.0416	0.639	9.05	0.981	0.987
1983	350	363	14	0.982	4.04	0.0177	0.0227	0.915	4.55	0.997	0.998
1984	10	33	24	0.986	3.83	0.0138	0.0147	1.004	4.55	0.997	0.991
1984	50	75	26	0.988	3.65	0.0117	0.0127	0.996	4.28	0.998	0.991
1984	104	121	18	0.976	9.46	0.0238	0.0356	0.883	11.8	0.995	0.999
1984	211	219	9	0.939	11.7	0.0633	0.0601	1.017	15	0.997	0.995
1984	322	334	13	0.944	3.87	0.0580	0.1135	0.789	5.8	0.984	0.996
1984	354	366	13	0.966	5.11	0.0345	0.0429	0.942	6.4	0.996	0.996
1985	20	45	26	0.984	2.08	0.0164	0.0160	1.036	2.6	0.992	0.988
1985	85	96	12	0.983	2.48	0.0167	0.0138	1.117	2.74	0.989	0.982
1985	113	130	18	0.975	6.05	0.0255	0.0394	0.880	7.7	0.987	0.997
1985	160	170	11	0.942	45.3	0.0599	0.0503	1.061	60.3	0.998	0.996
1985	173	188	16	0.946	20.7	0.0558	0.0619	0.975	32.2	0.994	0.995
1985	211	231	21	0.966	6.62	0.0351	0.0126	1.388	9.47	0.992	0.970
1985	345	359	15	0.983	2	0.0171	0.0193	0.978	2.28	0.994	0.996
1986	15	28	14	0.983	2.19	0.0172	0.0387	0.731	2.49	0.988	0.989
1986	63	77	15	0.979	2.71	0.0208	0.0169	1.093	3.15	0.997	0.993
1986	125	138	14	0.967	18.4	0.0334	0.0408	0.925	22.8	0.985	0.987
1986	170	190	21	0.965	8.46	0.0361	0.0868	0.722	12.3	0.997	0.991
1986	317	327	11	0.968	2.38	0.0327	0.0462	0.915	2.89	0.982	0.978
1986	346	357	12	0.976	2.85	0.0247	0.0266	0.993	3.3	0.995	0.995
1987	35	53	19	0.988	1.49	0.0125	0.0142	0.996	1.69	0.987	0.984
1987	66	76	11	0.983	2.16	0.0169	0.0143	1.078	2.35	0.999	0.995
1987	97	107	11	0.938	12	0.0641	0.0535	1.100	16.8	0.997	0.992
1987	163	179	17	0.965	10.6	0.0355	0.0173	1.249	13.8	0.990	0.983
1987	184	192	9	0.953	6.76	0.0483	0.0398	1.058	8.12	0.977	0.988
1987	312	321	10	0.938	3.55	0.0640	0.1080	0.810	4.85	0.992	0.998
1987	350	365	16	0.958	3.63	0.0424	0.0423	1.027	5.1	0.994	0.994

Table 5. Calculated Wilmot River base flow

Monthly and Annual Mean Base Flow (Discharge in Cubic Meters per Second)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1972	0.192	0.165 *	0.246	0.772	1.255	0.711	0.505	0.407	0.363	0.364	0.573	0.697	0.521
1973	0.705	0.556	0.601	0.761	0.690	0.587	0.503	0.438	0.384	0.336	0.298	0.302	0.513
1974	0.332	0.316	0.294	0.484	0.544	0.458	0.381	0.322	0.292	0.289	0.382	0.820	0.410
1975	0.535	0.332	0.304	1.171	2.072 *	0.844	0.510	0.394	0.348	0.309	0.288	0.338	0.620
1976	0.371	0.527	0.476	0.822	0.711	0.513	0.406	0.382	0.418	0.513	0.941	0.835	0.576
1977	0.624	0.451	0.577	0.922	0.863	0.738	0.632	0.539	0.480	0.655	0.847	0.858	0.682
1978	1.239	0.890	0.756	1.673	1.453	0.744	0.552	0.428	0.345	0.337	0.341	0.263	0.752
1979	0.566	0.395	0.588	0.697	0.611	0.483	0.409	0.485	0.493	0.619	0.767	0.945	0.588
1980	0.862	0.560	0.607	0.670	0.516	0.403	0.355	0.325	0.307	0.303	0.388	0.760	0.505
1981	0.623	1.055	0.879	0.926	0.821	0.763	0.774	0.573	0.473	0.508	0.872	1.255	0.793
1982	1.005	0.734	0.855	2.035	1.701	0.822	0.566	0.471	0.412	0.362	0.326	0.391	0.807
1983	0.511	0.430	0.732	0.956	0.878	0.685	0.539	0.485	0.502	0.468	0.465	0.750	0.617
1984	0.762	0.963	1.017	1.327	1.384	1.054	0.778	0.609	0.549	0.497	0.457	0.423	0.818
1985	0.346	0.295	0.535	0.753	0.740	0.676	0.536	0.432	0.361	0.313	0.273	0.241	0.458
1986	0.224	0.212	0.250	0.642	0.522	0.400	0.343	0.323	0.308	0.294	0.293	0.363	0.348
1987	0.339	0.276	0.286	1.198	0.743	0.500	0.413	0.341	0.313	0.320	0.444	0.623	0.483
1988	0.502	0.550	0.692	1.986	1.690	0.836	0.542	0.438	0.364	0.387	0.518	0.566	0.756
MEAN	0.573	0.512	0.570	1.047	1.011	0.660	0.514	0.435	0.395	0.404	0.498	0.613	0.603
STD	0.280	0.263	0.237	0.464	0.483	0.182	0.128	0.086	0.079	0.116	0.223	0.286	0.146
CV	0.489	0.513	0.416	0.443	0.478	0.276	0.249	0.197	0.199	0.288	0.448	0.466	0.242

* minimum and maximum values.

Table 6. Calculated Kouchibouguac River flow

Monthly and Annual Mean Base Flow (Discharge in Cubic Meters per Second)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1970	1.186	0.604	0.688	3.843	4.673	2.130	0.856	0.820	1.434	1.662	2.118	1.665	1.807
1971	1.144	1.364	1.997	11.855 *	6.035	1.479	1.019	0.639	0.356	0.374	0.509	1.010	2.315
1972	0.802	0.499	0.760	2.730	5.064	2.152	1.240	0.879	0.646	1.503	3.057	1.963	1.774
1973	1.542	1.327	1.868	4.857	4.187	1.686	0.884	0.657	0.513	0.499	0.923	2.688	1.803
1974	1.694	0.699	1.418	5.124	5.919	1.836	1.463	1.101	0.733	1.514	1.509	1.013	2.002
1975	0.953	0.577	0.785	5.146	6.927	2.317	0.845	0.479	0.389	0.463	1.447	1.784	1.843
1976	1.422	2.336	2.302	6.224	3.983	1.160	1.131	1.085	0.723	2.425	2.623	1.085	2.208
1977	0.900	0.751	1.270	10.020	8.398	2.508	1.032	0.524	0.418	2.266	2.207	1.386	2.640
1978	1.596	1.319	1.295	3.971	4.775	1.557	0.594	0.299	0.256	0.596	0.605	0.451	1.443
1979	1.291	1.596	4.121	6.448	3.676	1.389	0.692	0.677	0.656	0.805	0.938	0.944	1.936
1980	1.141	0.698	0.913	4.849	3.233	1.267	1.316	1.089	0.954	1.757	1.973	1.503	1.724
1981	0.847	1.029	2.720	5.919	3.954	2.122	1.185	0.808	0.914	1.971	2.910	2.476	2.238
1982	1.322	0.947	1.440	6.273	4.251	1.294	0.779	0.832	1.708	1.360	1.482	1.369	1.922
1983	0.684	0.811	1.814	5.430	3.423	1.630	0.784	0.407	0.349	0.382	1.555	2.607	1.656
1984	1.079	0.792	1.540	9.120	10.200	2.929	1.747	1.035	0.731	0.623	0.532	0.455	2.565
1985	0.387	0.405	0.977	2.811	2.852	3.099	1.127	0.492	0.236 *	0.320	0.458	0.376	1.128
1986	0.368	0.394	0.579	2.978	2.356	1.286	0.700	0.569	0.770	0.931	0.825	0.741	1.041
1987	0.668	0.605	0.704	5.979	2.778	0.961	0.434	0.266	0.301	0.681	1.173	1.202	1.313
1988	0.913	0.936	1.192	6.344	3.256	1.325	0.657	0.461	0.463	0.794	2.129	1.464	1.661
MEAN	1.049	0.931	1.494	5.785	4.734	1.796	0.973	0.691	0.661	1.094	1.506	1.418	1.822
STD	0.380	0.482	0.866	2.392	2.018	0.605	0.327	0.267	0.389	0.662	0.806	0.702	0.433
CV	0.362	0.518	0.580	0.413	0.426	0.337	0.336	0.387	0.589	0.605	0.535	0.495	0.237

* minimum and maximum values.

Table 7. Calculated Ste. Genevieve River base flow

Monthly and Annual Mean Base Flow (Discharge in Cubic Meters per Second)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1970	6.141	5.295	5.005	5.978	15.315	15.939	9.842	6.594	5.043	4.845	5.605	6.490	7.674
1971	6.195	4.974	4.283	8.178	18.360	16.092	9.496	7.139	8.059	6.004	5.217	4.752	8.229
1972	2.853	1.552	1.461 *	2.584	6.206	17.220	13.884	9.413	6.418	5.157	5.092	4.641	6.373
1973	3.643	4.311	3.823	5.411	14.174	15.470	9.807	6.167	3.911	3.003	2.748	2.577	6.254
1974	2.375	2.187	2.041	2.830	6.796	14.581	10.053	6.583	4.484	4.807	5.873	6.260	5.739
1975	4.612	3.418	2.629	3.815	9.740	12.326	7.717	4.214	2.655	3.138	4.606	6.532	5.450
1976	5.768	4.759	4.542	10.708	14.847	8.431	4.765	3.094	3.135	4.127	6.605	9.348	6.677
1977	8.428	5.544	3.977	7.271	16.762	19.237 *	10.596	6.935	6.581	11.077	7.254	4.617	9.023
1978	4.062	3.785	3.528	3.733	13.817	14.106	9.843	6.826	4.760	4.031	4.110	4.380	6.415
1979	6.452	5.888	9.393	10.143	8.201	6.630	5.598	6.417	8.103	8.038	7.413	6.890	7.430
1980	6.621	5.079	3.701	4.587	14 185	15.394	10.708	7.401	6.538	7.871	9.048	6.537	8.139
1981	4.128	4.589	6.011	7.396	13.226	9.165	5.111	3.193	2.549	5.193	5.188	5.986	5.978
1982	5.813	4.164	3.489	5.853	14.799	15.780	9.276	5.402	4.297	3.951	6.096	5.694	7.051
1983	3.861	2.946	2.622	4.068	8.016	8.766	6.082	5.162	4.427	4.467	4.297	3.798	4.876
1984	3.443	3.269	3.516	6.028	14.014	18.761	12.114	6.149	3.198	2.173	2.515	3.144	6.527
1985	2.383	1.823	2.034	2.915	7.505	17.264	9.515	4.728	3.615	3.390	2.590	1.975	4.978
1986	1.915	2.106	2.450	7.594	15.540	8.166	4.300	2.238	1.626	1.801	2.006	2.342	4.340
1987	1.961	1.474	2.244	8.562	18.304	11.100	5.048	2.685	2.100	2.300	2.679	2.717	5.098
MEAN	4.481	3.731	3.708	5.981	12.767	13.579	8.542	5.574	4.528	4.672	4.889	4.989	6.355
STD	1.880	1.445	1.835	2.473	3.958	3.949	2.781	1.901	1.942	2.294	1.915	1.923	1.331
CV	0.420	0.387	0.495	0.414	0.310	0.291	0.326	0.341	0.429	0.491	0.392	0.386	0.209

* minimum and maximum values.

Table 8. Ratio of base flow to total flow for Wilmot River

Monthly and Annual Mean Base Flow (Discharge in Cubic Meters per Second)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1972	0.380	0.248	0.156	0.354	0.428	0.890	0.957	0.959	0.961	0.841	0.800	0.885	0.655
1973	0.419	0.420	0.310	0.689	0.720	0.903	0.828	0.841	0.880	0.860	0.926	0.807	0.717
1974	0.506	0.374	0.248	0.346	0.865	0.916	0.845	0.889	0.886	0.740	0.652	0.853	0.677
1975	0.880	0.896	0.531	0.452	0.856	0.948	0.934	0.876	0.895	0.870	0.833	0.494	0.789
1976	0.306	0.258	0.350	0.803	0.861	0.938	0.895	0.850	0.662	0.702	0.714	0.480	0.651
1977	0.573	0.709	0.218	0.349	0.823	0.766	0.868	0.930	0.892	0.524	0.835	0.655	0.678
1978	0.471	0.804	0.501	0.558	0.914	0.941	0.957	0.921	0.914	0.809	0.958	0.898	0.804
1979	0.242	0.295	0.289	0.613	0.888	0.849	0.655	0.833	0.908	0.717	0.547	0.625	0.622
1980	0.727	0.940	0.440	0.658	0.903	0.930	0.921	0.898	0.890	0.867	0.718	0.685	0.798
1981	0.818	0.441	0.739	0.800	0.924	0.769	0.900	0.970	0.973 *	0.663	0.635	0.674	0.775
1982	0.794	0.756	0.650	0.661	0.834	0.917	0.911	0.940	0.916	0.877	0.942	0.716	0.826
1983	0.797	0.732	0.436	0.701	0.866	0.687	0.864	0.541	0.744	0.857	0.854	0.688	0.731
1984	0.909	0.524	0.403	0.560	0.835	0.820	0.839	0.820	0.874	0.870	0.891	0.836	0.765
1985	0.867	0.905	0.556	0.589	0.809	0.830	0.962	0.940	0.946	0.850	0.801	0.673	0.811
1986	0.118	0.496	0.114 *	0.404	0.838	0.960	0.846	0.811	0.949	0.917	0.755	0.666	0.656
1987	0.813	0.818	0.515	0.370	0.946	0.770	0.916	0.940	0.896	0.858	0.730	0.724	0.775
1988	0.893	0.561	0.361	0.652	0.935	0.942	0.949	0.933	0.934	0.643	0.741	0.768	0.776
MEAN	0.618	0.599	0.401	0.562	0.838	0.869	0.885	0.876	0.889	0.792	0.784	0.713	0.736
STD	0.258	0.237	0.171	0.156	0.119	0.082	0.074	0.100	0.077	0.108	0.114	0.120	0.067
CV	0.417	0.396	0.426	0.277	0.142	0.094	0.084	0.114	0.087	0.137	0.145	0.168	0.090

* minimum and maximum values.

Table 9. Ratio of base flow to total flow for Kouchibouguac River

Monthly and Annual Mean Base Flow (Discharge in Cubic Meters per Second)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1970	0.596	0.141	0.491	0.585	0.711	0.640	0.597	0.453	0.290	0.327	0.655	0.858	0.529
1971	0.903	0.466	0.682	0.572	0.560	0.808	0.483	0.842	0.848	0.610	0.437	0.606	0.651
1972	0.732	0.682	0.431	0.497	0.255	0.537	0.534	0.491	0.718	0.463	0.563	0.544	0 537
1973	0.525	0.517	0.423	0.376	0.494	0.667	0.369	0.387	0.710	0.878	0.567	0.460	0.531
1974	0.916	0.835	0.694	0.537	0.709	0.790	0.316	0.703	0.562	0.462	0.756	0.107 *	0.616
1975	0.693	0.823	0.613	0.625	0.371	0.431	0.642	0.724	0.605	0.647	0.488	0.490	0.596
1976	0.589	0.435	0.629	0.453	0.649	0.720	0.308	0.346	0.731	0.492	0.651	0.602	0.551
1977	0.539	0.866	0.585	0.549	0.700	0.242	0.766	0.748	0.427	0.259	0.659	0.624	0.580
1978	0.417	0.553	0.682	0.410	0.420	0.695	0.676	0.839	0.716	0.453	0.657	0.901	0.618
1979	0.195	0.351	0.405	0.451	0.405	0.460	0.680	0.395	0.628	0.524	0.206	0.409	0.426
1980	0.424	0.866	0.570	0.379	0.574	0.727	0.563	0.656	0.622	0.485	0.353	0.296	0.543
1981	0.768	0.184	0.660	0.340	0.646	0.572	0.710	0.461	0.467	0.319	0.435	0.310	0.489
1982	0.722	0.515	0.743	0.464	0.785	0.552	0.349	0.386	0.492	0.761	0.388	0.727	0.574
1983	0.681	0.644	0.518	0.551	0.570	0.414	0.706	0.805	0.570	0.593	0.326	0.470	0.571
1984	0.965 *	0.561	0.537	0.583	0.624	0.353	0.530	0.883	0.695	0.716	0.540	0.394	0.615
1985	0.611	0.713	0.499	0.559	0.536	0.496	0.676	0.730	0.630	0.623	0.251	0.544	0.572
1986	0.286	0.290	0.426	0.171	0.409	0.356	0.731	0.402	0.429	0.712	0.635	0.392	0.437
1987	0.684	0.836	0.669	0.348	0.761	0.674	0.585	0.661	0.263	0.394	0.556	0.386	0.568
1988	0.552	0.459	0.298	0.470	0.652	0.743	0.625	0.439	0.540	0.299	0.404	0.610	0.508
MEAN	0.621	0.565	0.555	0.469	0.570	0.572	0.571	0.597	0.576	0.527	0.501	0.512	0.553
STD	0.202	0.227	0.122	0.113	0.146	0.164	0.145	0.186	0.153	0.171	0.154	0.193	0.059
CV	0.326	0.401	0.219	0.240	0.256	0.287	0.254	0.312	0.266	0.324	0.306	0.377	0.107

* minimum and maximum values.

Table 10. Ratio of base flow to total flow for Ste. Genevieve River

Monthly and Annual Mean Base Flow (Discharge in Cubic Meters per Second)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1970	0.864	0.795	0.870	0.813	0.757	0.915	0.866	0.817	0.871	0.724	0.809	0.649	0.813
1971	0.812	0.909	0.939	0.680	0.582	0.773	0.847	0.828	0.840	0.804	0.835	0.882	0.811
1972	0.698	0.886	0.537	0.221 *	0.601	0.573	0.764	0.843	0.874	0.827	0.818	0.693	0.695
1973	0.906	0.836	0.906	0.887	0.771	0.836	0.773	0.636	0.816	0.819	0.781	0.493	0.788
1974	0.515	0.762	0.929	0.807	0.436	0.687	0.722	0.774	0.845	0.651	0.777	0.789	0.725
1975	0.942	0.991 *	0.889	0.716	0.584	0.747	0.865	0.861	0.852	0.763	0.623	0.687	0.793
1976	0.836	0.730	0.790	0.490	0.740	0.686	0.806	0.765	0.821	0.666	0.566	0.833	0.727
1977	0.803	0.934	0.807	0.557	0.730	0.595	0.887	0.856	0.826	0.670	0.697	0.699	0.755
1978	0.490	0.823	0.977	0.874	0.640	0.680	0.798	0.866	0.793	0.821	0.766	0.781	0.776
1979	0.584	0.651	0.503	0.925	0.468	0.655	0.885	0.838	0.693	0.841	0.614	0.789	0.704
1980	0.777	0.867	0.935	0.757	0.841	0.844	0.895	0.816	0.814	0.782	0.652	0.615	0.800
1981	0.935	0.614	0.830	0.828	0.782	0.866	0.897	0.553	0.694	0.749	0.894	0.535	0.765
1982	0.727	0.913	0.862	0.640	0.644	0.715	0.893	0.924	0.716	0.893	0.729	0.817	0.789
1983	0.876	0.855	0.799	0.475	0.524	0.739	0.862	0.563	0.816	0.672	0.557	0.802	0.712
1984	0.856	0.753	0.609	0.617	0.632	0.675	0.766	0.791	0.905	0.910	0.664	0.646	0.735
1985	0.822	0.763	0.659	0.520	0.549	0.440	0.677	0.851	0.744	0.730	0.618	0.858	0.686
1986	0.720	0.429	0.762	0.776	0.898	0.647	0.821	0.884	0.862	0.784	0.757	0.729	0.756
1987	0.770	0.831	0.729	0.574	0.839	0.890	0.912	0.950	0.765	0.616	0.569	0.552	0.750
MEAN	0.774	0.797	0.796	0.675	0.668	0.720	0.830	0.801	0.808	0.762	0.707	0.714	0.754
STD	0.133	0.133	0.140	0.181	0.133	0.122	0.068	0.111	0.062	0.084	0.103	0.115	0.040
CV	0.172	0.167	0.176	0.268	0.200	0.169	0.081	0.138	0.077	0.111	0.146	0.161	0.054

* minimum and maximum values.

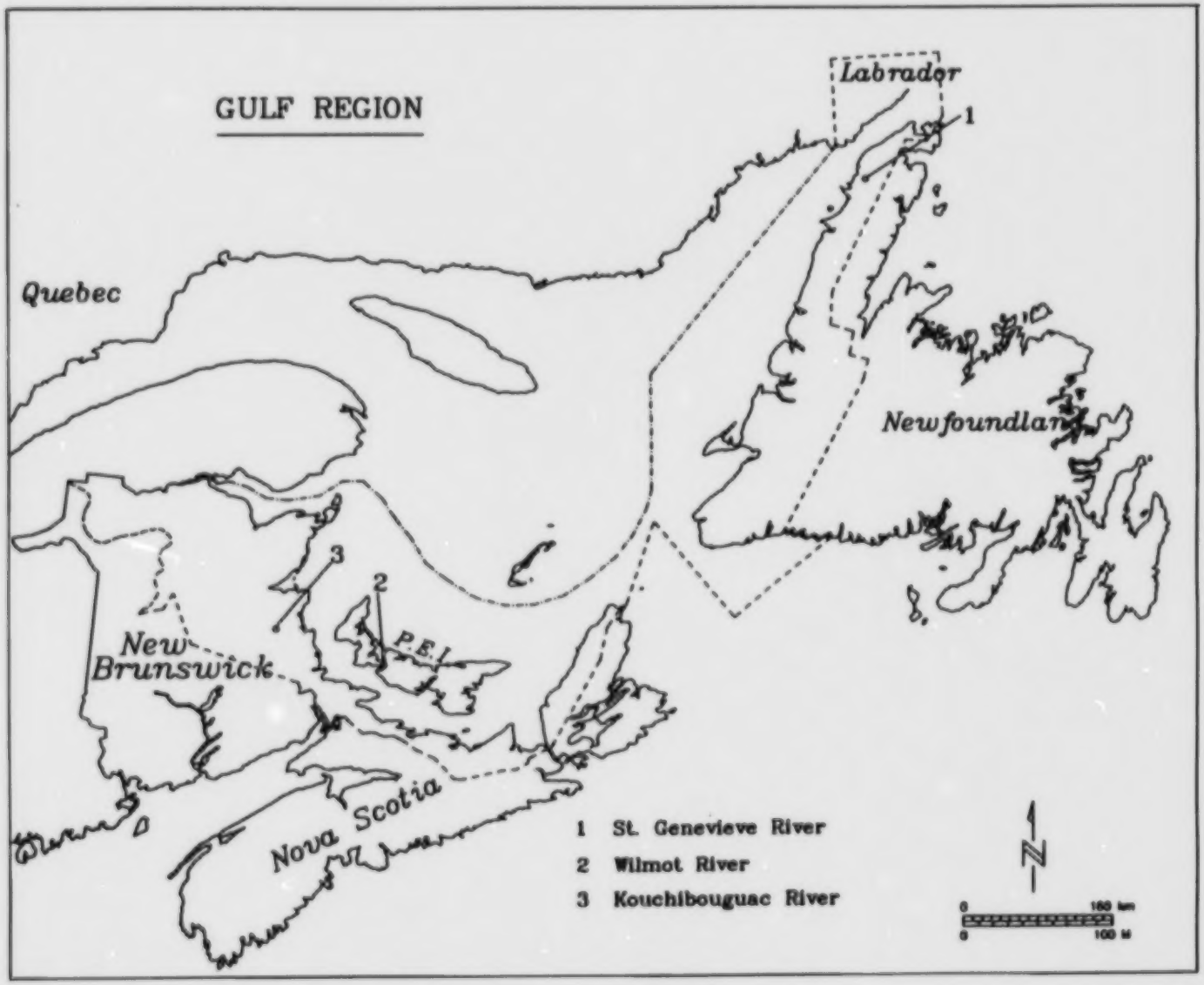

Figure 1. Gulf Region map indicating studied drainage basins.

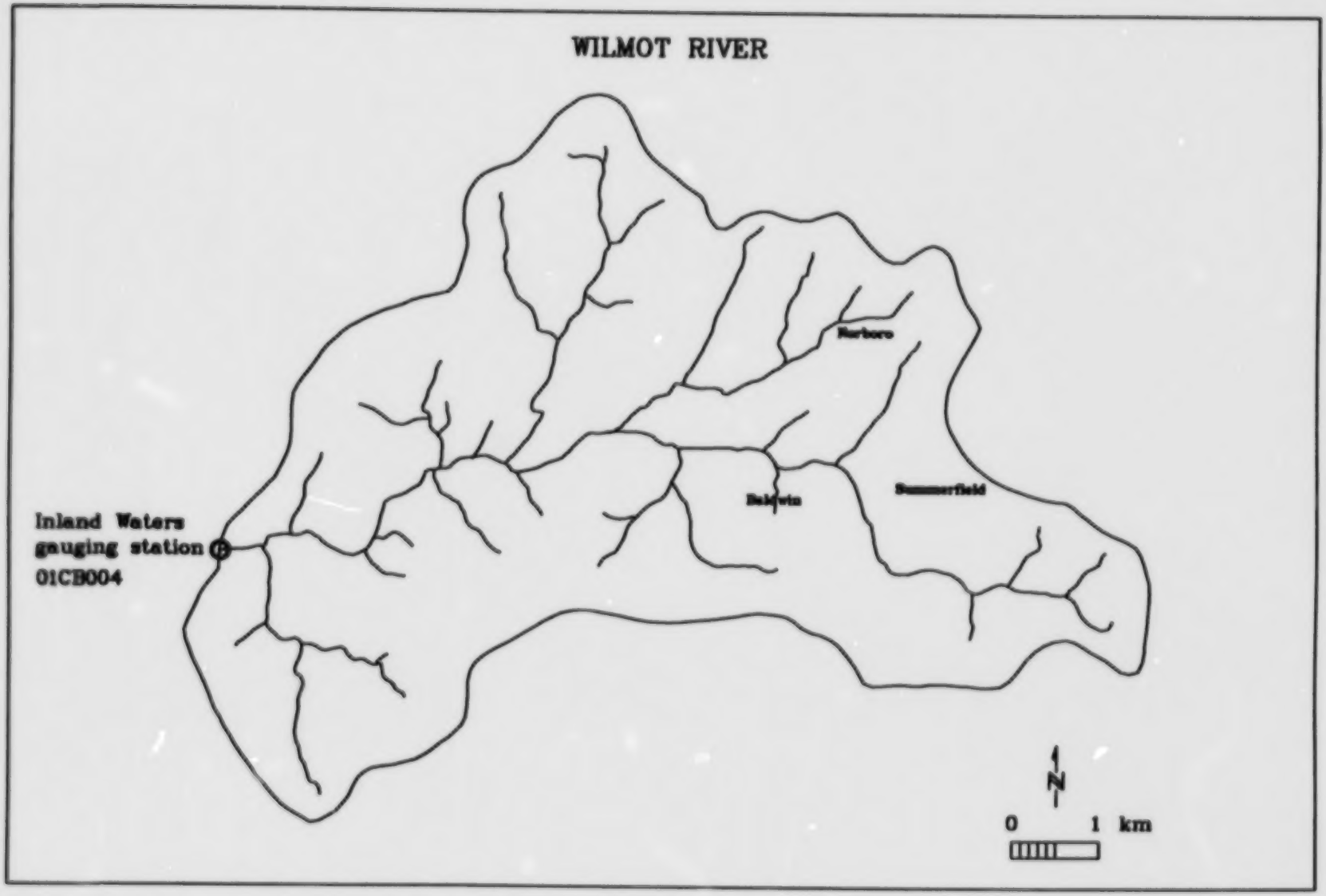

Figure 2. Wilmot River near Wilmot Valley, PEI. – station no. 01BC004

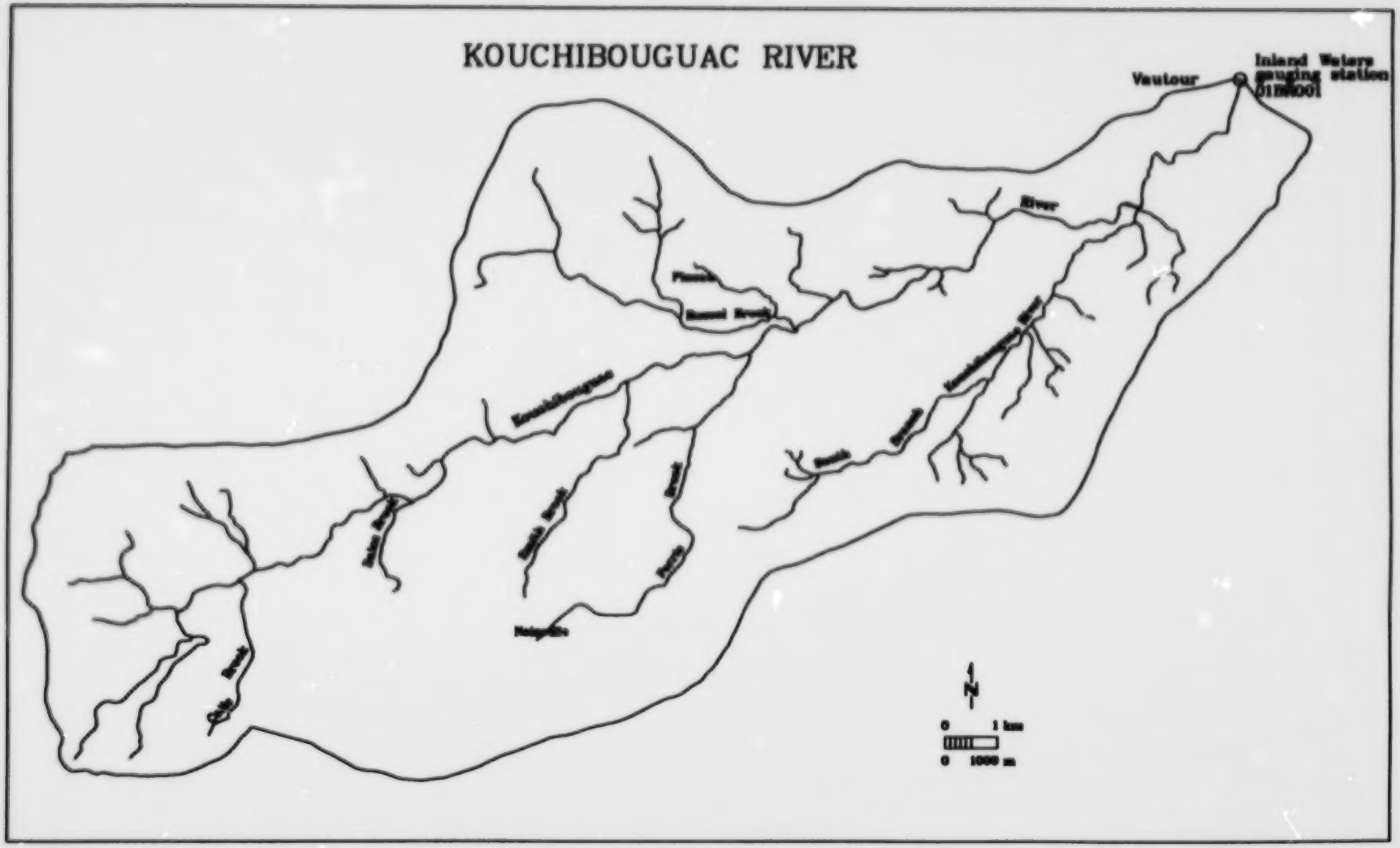

Figure 3. Kouchibouguac River near Vautour, NB – station no. 01BR001

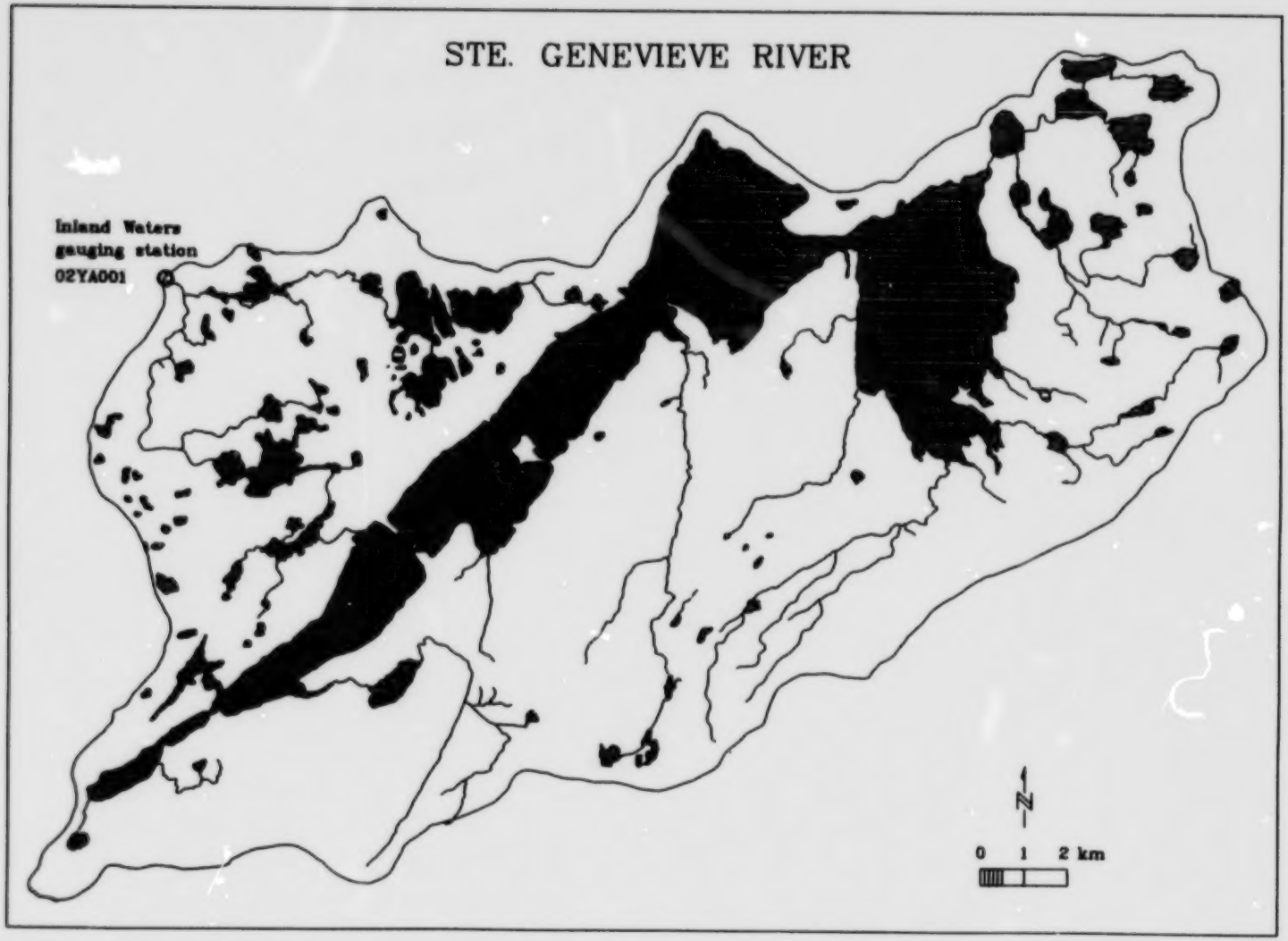

Figure 4. Ste. Genevieve River near Forresters Point, Nfld. – station no. 02YA001

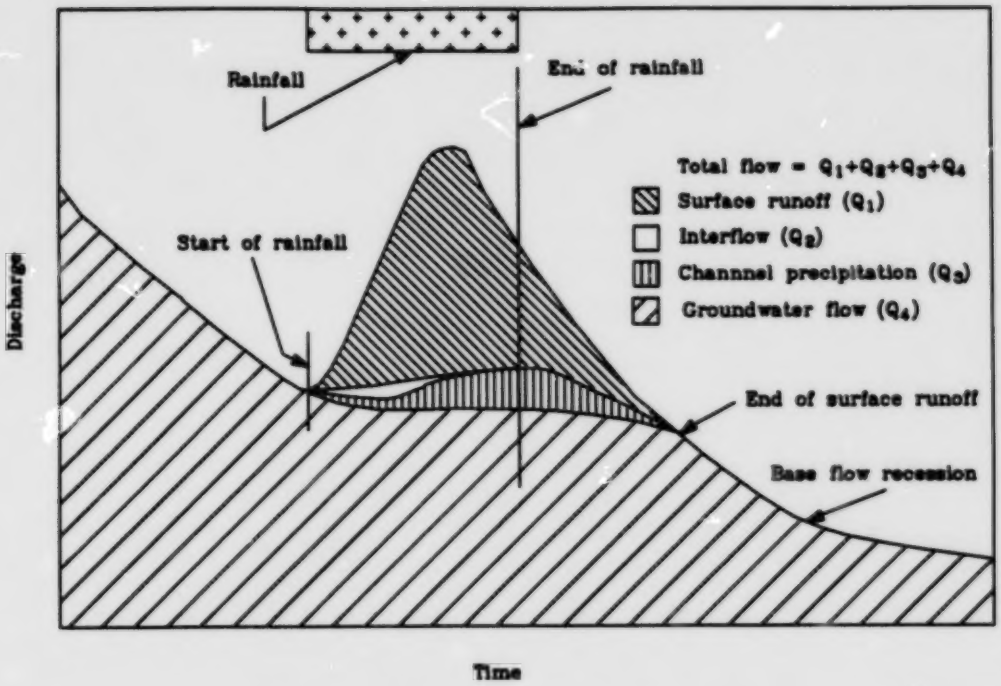

Figure 5. Streamflow Components (Viessman et al. 1977)

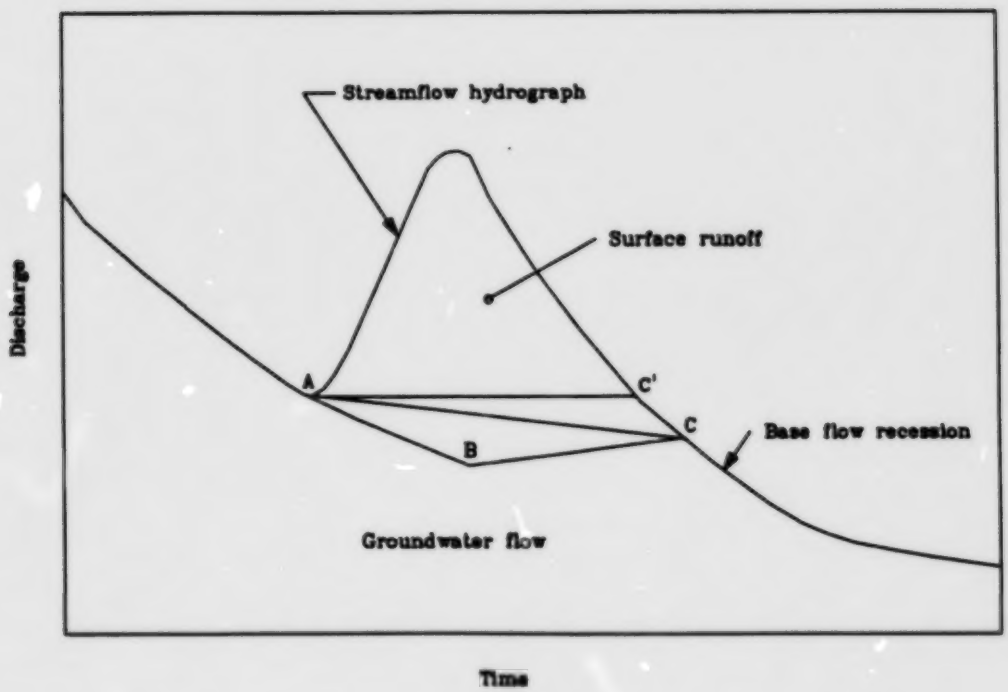

Figure 6. Hydrograph separation techniques (see text for explanation of symbols)

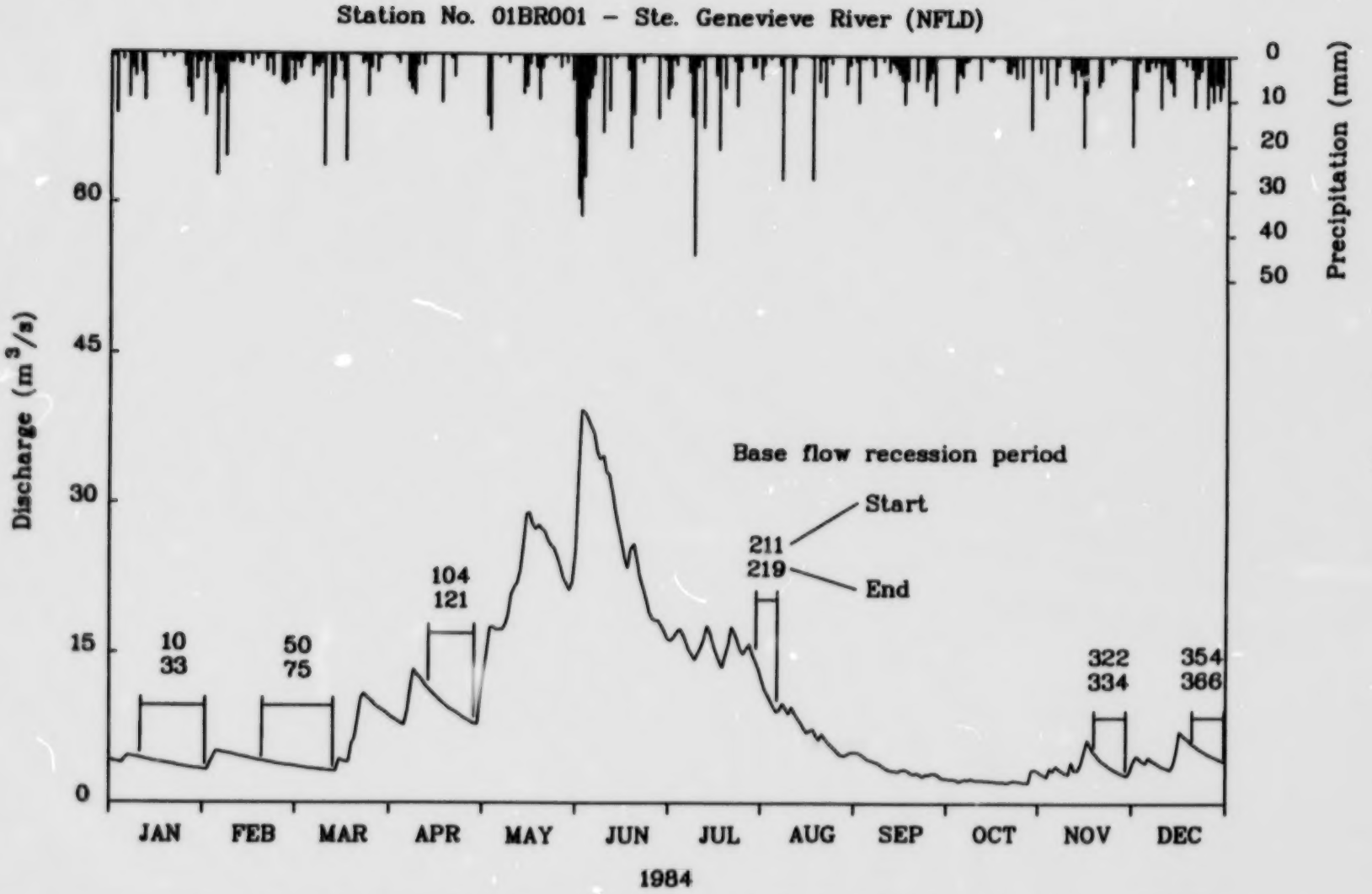

Figure 7. Identification of base flow recession periods for Ste. Genevieve River (1984) based on discharge. Numbers refer to the Julian day range for each recession period.

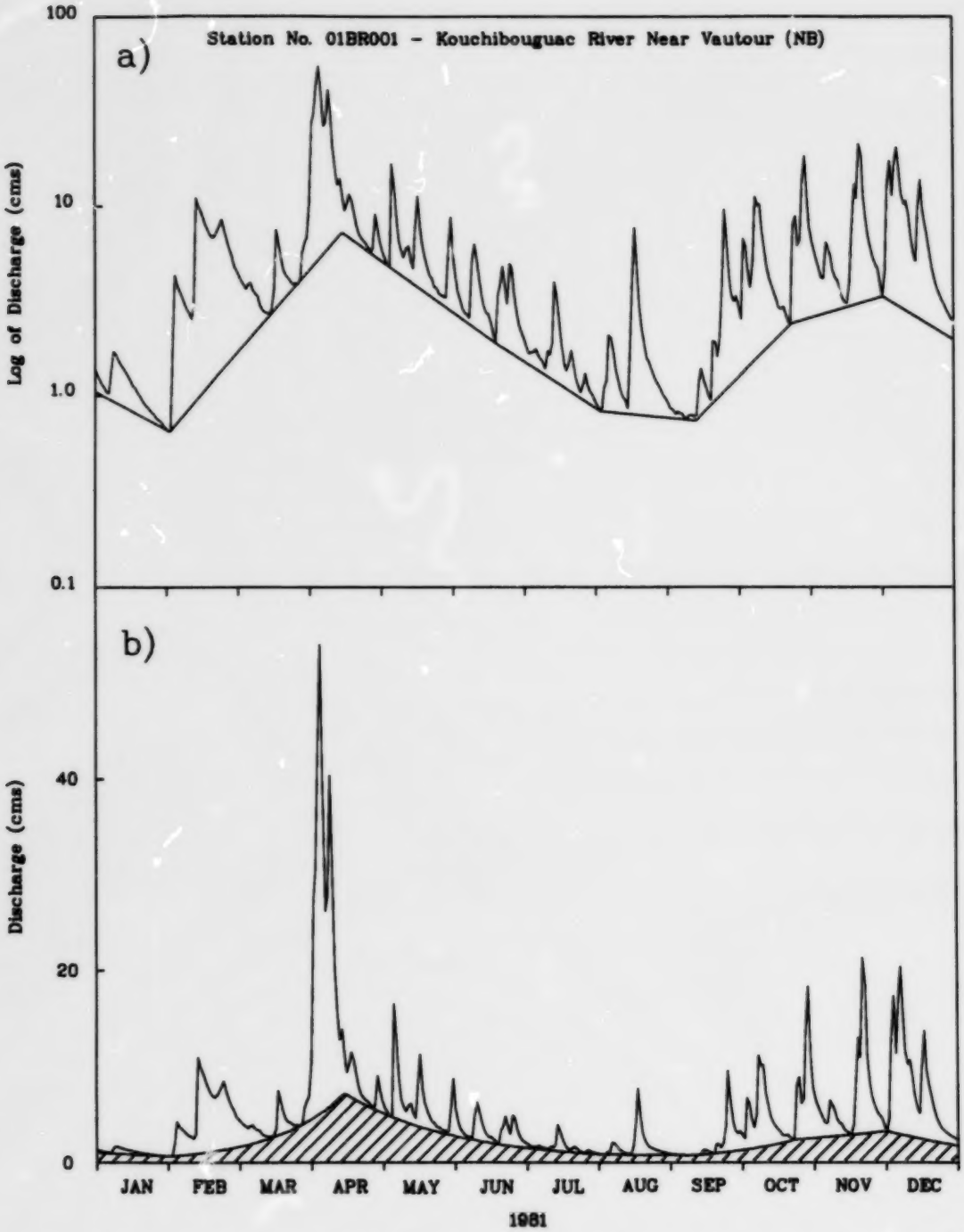

Figure 8. Base flow hydrograph separation for Kouchibouguac River (1981)